



B06: CMS Subproject QA Implementation

Carol Wilkinson

HL-LHC CMS Associate Project Manager

CD-1 Director's Review

March 19-21, 2019





U.S. CMS Subproject QA Implementation

Charge #6

Charge #8

Major components for U.S. CMS Subproject (L2) QAP implementation:

- Individual QA Implementation Plans (QAP Appendix [CMS-doc-13093](#))
- QA Activities Spreadsheets ([CMS-doc-13093](#))
 - Summary list of QA/QA activities with links to Technical Requirements
- Detailed QA/QC procedures and plans at component level
- Experienced, dedicated, and pro-active technical leads

Charge #6 (Adequately mature QA) and Charge #8 (Response to reviews)



Outline

- Biographical Sketch
- Overview of Subproject QA Implementation
- Subproject QA Plans (QAP Appendix)
 - Outer Tracker example
- Subproject QA Activities Spreadsheets
 - Outer Tracker and MIP Timing Detector examples
- Subcomponent QA Plans and Procedures
 - MTD and Endcap Calorimeter examples
- Qualifications and Training
 - Endcap Calorimeter example
- Status / Summary



Biographical Sketch - Carol Wilkinson (Assoc. PM)

- Project Management Consultant for large scientific facilities
 - 25+ years of experience in managing large scientific facilities for DOE and NSF.
 - Panelist for many external reviews of NSF and DOE facility construction / operations
- Caltech Science Research Manager (2003 – 2017)
 - Advanced LIGO Project Manager (2003 -2013)
 - Visiting Facility Advisor with NSF Large Facilities Office (2013-2016)
- Los Alamos Project Manager - Nuclear Weapons Hydrotesting Program (2002 – 2003)
- Los Alamos Group Leader – DAHRT Accelerator Operations; and Project Manager – DAHRT Facility Construction (1999-2002)
- Los Alamos Deputy Group Leader – DAHRT Accelerator Operations; and Deputy Project Manager– DAHRT Facility Construction(1998-1999)
- Los Alamos LAMPF Team Leader - Beam Line and Accelerator Physics (1989-1998)



Subproject Implementation of the US CMS Quality Assurance Plan (Appendix)



[CMS-doc-13093](#)

Appendix to the
Quality Assurance Plan for the U.S. CMS HL-
LHC Project

Appendix Revision 2
March 1, 2019

CMS-doc-13093

- The QAP defines general Quality Assurance expectations from international CMS through Fermilab to participating institutions in the U.S.
- Subproject appendices detail how each will implement the QAP given the different organizational structures and interactions within international CMS
- QA roles, responsibilities, and processes may vary in detail from subproject to subproject

Controlled document approved by U.S. CMS
PM, Deputy PM, and QA Coordinator



QAP Subproject Appendix Contents

[CMS-doc-13093](#)

The QAP appendix contains high level descriptions of QA implementation for each L2 U.S. CMS subproject, including:

- Short description of the **scope of work** / deliverables (designs, prototypes, hardware, software, test results, etc.)
- Subdetector **organization and communication** methods within CMS and U.S. CMS
- List of **participating institutions** within U.S. CMS
- Short description of the types of **QA activities** (electronic prototyping, simulations or other modeling, material testing, vendor validation, assembly, QC, performance testing, etc.)
- Management of **non-conforming parts**
- **Document and Record** keeping



Ex: Outer Tracker - Scope

A.2.1 Outer Tracker Project Scope

The Outer Tracker (OT) detector is a subsystem within the international CMS Subdetector Upgrade Tracker Project. It is an array of silicon sensors that collects space points from the ionization of charged particle tracks, operating in a high radiation environment inside the CMS Calorimeters and Magnet. The space points are used to reconstruct particle trajectories and provide trigger information for charged particles (especially muons) above a transverse momentum threshold. The design entails the use of sensor doublets or 'sandwiches' to form modules: a pixel sensor-strip sensor sandwich for smaller radii forms a PS module, and a strip sensor-strip sensor (2S) sandwich forms a 2S module for larger radii. Pixel-Strip sensors (PS-s) and Strip-Strip sensors (2S) provide 1D information, pixelated sensors (PS-p) provide 2D information. Modules include sensors, ASICs, power and readout hybrids, spacers and mechanical support. Mechanics are similar for both modules although the sensors and electronics differ.

The U.S. OT subproject is integrated with international CMS with respect to shared designs, procurements, and module production. Deliverables for the U.S. effort include PS modules passed to Outer Tracker collaborators; PS modules assembled into planks and rings and integrated into the PS Flat Barrel structure; 2S modules; and the design/development of assembly procedures, assembly facilities, and test systems to support component and module QC. The development of the required radiation tolerant sensors and readout electronics is outside the scope of this project. The U.S. OT WBS for deliverables is

- 402.2.2 Management
 - Travel for Organizational Meetings and Misc. M&S
- 402.2.3 Sensors
 - Procurement of Sensors, Setup up and Execution of QC
- 402.2.4 Electronics

OT Scope:
Participation in design, production, and performance testing of sensor modules, electronics, and assemblies.

Sample page



Subproject Organization

- Roles defined within the specific CMS subdetector system
 - U.S. leads report to one or more CMS subdetector leads
 - Responsibilities may be held at CSM level or delegated to subproject leads
 - Some U.S. leads also have lead roles in CMS organization
- Subproject may be uniquely in charge of a subcomponent effort or may share tasks with other CMS collaborators.
 - Responsibility for defining procedures will vary, although approval rests with CMS
- Communication and decision-making varies by subdetector, although most rely on consensus of collaborators



Ex: Outer Tracker– Organization & Interfaces

A.2.2 Outer Tracker Project Organization

U.S. CMS OT reports to the international CMS Subdetector Upgrade Coordinator for the L1 Upgrade Tracker Project, along with Inner Tracker (aka Pixels, U.S. NSF scope) and Track Trigger (part of U.S. Trigger/DAQ subproject, NSF and DOE scope)¹. The U.S. is one of 11 entities – 10 countries plus CERN – that provide some subset of the Outer Tracker deliverables. The U.S. OT effort is homogeneously intertwined with the international CMS with respect to design validation, shared procurements organized through CERN to guarantee consistency, and fabrication in parallel, all coordinated and overseen by CMS Tracker. U.S. team members are embedded in the Tracker and CMS international organization: the U.S. team co-coordinates the System Test and Modules groups, as well as the CMS Upgrade Performance Studies” group. There are organization charts for CMS and US-CMS that define clear roles and responsibilities, as well as official channels for communication (see the Preliminary Project Management Plan for the HL-LHC CMS Detector Upgrade Project, [CMS Document 13104](#)).

The U.S. OT project planning and schedule are maintained independently from the CMS schedule, with deliverables to and from the U.S. project represented as external milestones. Key external interfaces are with CERN on procurements of silicon sensors and common electronics components (ASICs), with OT collaborators responsible for mechanical structures and DAQ, and with the receivers of U.S. OT deliverables.

Components for module assembly are delivered from vendors, acceptance tested, and used to build modules, which then are distributed to burn-in centers and finally integration centers to be built into larger structures. The overall scheme is shown in Figure 2-1. The U.S. flow, shown

OT Organization:

One of 11 collaborators producing Outer Tracker deliverables

- Responsible for a percentage of modules
- Shared designs, procurements, and procedures
- Multiple interfaces

Sample page



Ex: Outer Tracker Participating Institut'ns

The U.S. CMS OT subproject leverages existing experience and expertise at participating institutes (6 out of 9) and has already instituted cross-site exchanges to spread knowledge and expertise to new comers.

Institution	L3 Subcomponent	Activity
DOE Responsibility		
Brown	Sensor	Sensor design and production QC
Rochester	Sensor	Sensor design and production QC
Brown	Modules	Mechanical assembly of modules
Princeton	Modules	Electrical assembly of modules
Rutgers	Modules	Electrical assembly of modules
Fermilab	Modules	Mechanical and Electrical assembly of modules
Fermilab	Integrated assembly	Plank and Layer assembly
UC Davis*	Mechanics, Materials testing	Validation of mechanical properties of substrates
Wayne State*	DAQ; Modules Machining	Participation in DAQ and test beam work at Fermilab; machining of jigs and fixtures for module assembly
Bethel*	Module Assembly	Participation in QA activities in Module Assembly at SiDet
Iowa*	Module Assembly	Participation in Module Assembly at SiDet

*No site visit needed due to work being performed under the QA plan/procedure for another site or due to the nature of the work.

Nine U.S. Participating Institutions:

- design
- mechanical or electrical assembly
- performance testing
- production QA/QC

Sample page



Ex: Outer Tracker– Design Validation

A.2.4.1 Outer Tracker Design Validation

In all areas of the Outer Tracker, there are several planned iterations of prototyping and validation of prototype performance before/after irradiation where appropriate, including test beam performance. Several areas in Outer Tracker are almost completely Quality Assurance programs. For the Sensors, one of the major procurements in the HL-LHC project other than the actual procurement of the silicon sensors, the entire schedule is a plan to develop the procedures and testing infrastructure and then perform validation tests of the sensors, checking that they meet the specifications in terms of performance and radiation tolerance. In Electronics, the Test Systems L3 area is dedicated to the design of standardized test equipment and procedures to be used in all assembly sites for acceptance of components as well as validation of performance of the final assembled deliverable.

U.S. OT has passed an initial design review (See *report Sept 2017 Independent Outer Tracker Technical Review*, CMS-doc-13406), which established the main parameters and vetted the layout and sensor sandwich design through simulation. This report noted that QA for this project was well planned and executed. OT was also reviewed during the April 2018 HL LHC CD-1 Director's Review (CMS-doc-13535), in which the only committee comment relevant to Quality Assurance was positive. Finally, the project was reviewed as part of the June 2018 DOE CD-1 review, but the remarks (predominantly positive) do not bear on Quality issues.

In order to prepare for the next step in the Critical Decision process, which is a CD 2/3 in the fall of 2020, a series of iterations of prototype module fabrication with increasingly mature components is underway, which provides both a development path for perfecting the construction methods but also a method for refining estimates before baseline and developing the QC infrastructure and methodology.

Design QA Activity Summary:

Close coordination with CMS

- Module design/ prototyping
- sensor validation/ testing development
- technical reviews
- QA/QC plan development

Sample page



Ex: Outer Tracker - Production Verification

Charge #8

A.2.4.2 Outer Tracker Production Verification

All components will be checked first by the vendor as part of the Quality Control specifications in the contract, with contracts written such that only satisfactory parts are paid for/delivered. Vendor QC will be cross checked by visual inspection and, where appropriate, functional testing by the project team at the Sensor QA and Module Assembly sites. Items which do not conform will be graded as such and segregated from conforming components, to be either discarded or used in dedicated tests/mock-ups where the lack of functionality does not affect the test.

Module production is coordinated by the CMS module group and the US activities are embedded into the work of this group. The CMS module group will approve the tooling and procedures to be used for assembly and publish the approved designs. The institutional sites where fabrication of components will take place will be required to follow the International CMS designs and procedures, which applies to all participants in the Outer Tracker, independent of local institutional QA programs. To be approved for assembly of production modules, all assembly centers will have to demonstrate to the CMS module group that they can meet the requirements by reliably by assembling five modules to specifications.

In addition, U.S. subproject production Leads will follow the process described in the U.S. CMS QAP to validate demonstrated site capability for CMS designs and procedures after the prototyping campaign and to review/approve site QA plans/procedures. By default, the Institute PI serves as the QA point of contact for each site but may delegate that to the engineering or technical staff responsible for the daily operations. Site visits by the L2 Lead and the QA Coordinator will occur before the start of production. Continuous monitoring of the yield of recent fabrications will be performed by the assembly site personnel as well as L3 and L2 management throughout the production, with site follow-up visits if the yield becomes unsatisfactory. Weekly reports to L2 management of production throughput based on the standardized verification program will be used to judge progress as the production ensues.

Non-conforming Parts: Marked and segregated

Production QA Activity Summary:
Managed by CMS module group.

- Checks on vendor QC inspections
- Sensor validation testing
- Assembly site QA planning/mgt
- assembly performance testing

Sample page



Ex: Outer Tracker – Documentation

A.2.5 Outer Tracker Document/Record Storage

Project designs, plans, and reports shared between the U.S., other CMS Tracker detector stakeholders, and CERN engineering are maintained by the international organization, through the CERN Engineering Design Management System (EDMS), the CMS Document Database, or an online “e-space” built for collaborative work. These systems are meant to be the repository of the authoritative latest design and can have notification/approval mechanisms such that all stakeholders can be aware of and/or approve design changes. Implementation in EDMS is based on the 402.4 Calorimeter Endcap example and is ongoing.

Sample page

Tracking and Documentation:

CMS Technical Coordinator (TC) has ultimate responsibility to keep up-to-date documents, drawings. DocDB and CERN EDMS are the project storage sites, along with a shared e-space.

- maintenance and tracking of issue reports
- travelers and test records
- project plans and documents



QA Activity Spreadsheets

[CMS-doc-13093](#)

Summary of QA Activities by subproject

- Activity titles and descriptions
- Assigned responsibilities/contacts
- Referenced to technical engineering and/or scientific requirements
 - Plans and req's being finalized during remaining design phase
- References to procedures, related hardware, training, calibrations
- Working documents: expected to evolve and mature over time
- Cross-walk with subproject technical requirements spreadsheet to complete science flowdown



Ex: Outer Tracker QA Spreadsheet

- Activity titles, WBS, responsibilities, and QA process descriptions

<u>WBS</u>	<u>WBS Title</u>	<u>L2, L3, L4 Lead</u>	<u>Sub-Project/ Sub-component</u>	<u>Institution/ Work Area</u>	<u>QA Coordinator / Contact</u>	<u>QA Activity ID</u>	<u>Quality Control or Assurance Activity/</u>	<u>Validation / Verification Activities & Inspection / Acceptance Test Activities</u>
402.02.3-7	OT Technical WBS	Multiple	Global Tracker Construction Database	iCMS OT institutes	iCMS	OT-QA-001	Process Control	Database will be programmed to test and only accept valid input
402.02.05.01	Module Assembly Sites	L. Spiegel, M. Narain	Local Tracker Construction Database	FNAL/East Coast	L3s	OT-QA-002	Process Control	Database will be programmed to test and only accept valid input
402.02.03	Sensors	U. Heintz	Sensor QC development	Brown, Rochester	Hinton / Korjevanski	OT-QA-003	Measurement	Testing small sample of sensors from each delivered batch
402.02.03	Sensors	U. Heintz	Process QC Development	Brown, Rochester	Hinton / Korjevanski	OT-QA-004	Measurement	Testing test structures incorporated into the sensors wafers (flutes) to verify consistency of each sensor batch
402.02.03	Sensors	U. Heintz	Neutron Irradiation	Brown	Heintz	OT-QA-005	Measurement	Sample of sensors irradiated with neutrons to verify radiation tolerance



Ex: Outer Tracker QA Spreadsheet (cont.)

- Requirements, procedures, calibrations, records, training

WBS	WBS Title	QA Activity ID	Requirements/ Specifications	Tech Requirement ID	Tech Requirement Title	Measurement/ Method	Associated Hardware/ Software	Standard / Procedure / Process Doc	Calibration Planning	Record (Data, Calibration, etc.)	Training and Qualifications
402.02.3-7	OT Technical WBS	OT-QA-001	CMS DocDb Ref # 13680	OT-eng-29, OT-eng-38	PS/2S Module Assembly	All technical metrics and performance results are captured in a global database used by all proponents of the international Outer Tracker project, for all electronic and mechanical detector components and composite assemblies	Database Interface software	TBD	Not Needed	Physical dimensions, Electrical and/or Thermal parameters, Pedestal and Noise	Minor introduction to DB interface
402.02.05.01	Module Assembly Sites	OT-QA-002	Must maintain compatibility with global DB	OT-eng-29, OT-eng-38	PS/2S Module Assembly	Specific to the U.S., the module assembly sites will also utilize a local database to capture metrics and performance results, insuring continuous production during global database outages	Database Interface software, local DB implementation	TBD	Not Needed	Physical dimensions, Electrical and/or Thermal parameters, Pedestal and Noise	Minor introduction to DB interface
402.02.03	Sensors	OT-QA-003	CMS DocDb Ref # 13384, 13388	OT-eng-048, OT-eng-52, OT-eng-56	PS-p/PS-s/2S Sensor Layout	Sensor QC consists of a suite of tests on sensors done on a small fraction of sensors per wafer, to sample the sensor quality per wafer and verify sensor quality throughout production	Test Hardware and control software	<u>Sensor and Sensor QC specifications</u>	Periodic calibration with known standard candle, cross-calibration between sites	Test results stored in database, available through etraveler	Training on Sensor QC probe station and control software
402.02.03	Sensors	OT-QA-004	CMS DocDb Ref # 13384, 13389	OT-eng-048, OT-eng-52, OT-eng-56	PS-p/PS-s/2S Sensor Layout	Process QC consists of a suite of more incisive and potentially destructive tests done on test structures included in the sensor wafer mask, to verify wafer quality/consistency throughout production	Test Hardware and control software	Process QC intro Update	Periodic calibration with known standard candle, cross-calibration between sites	Test results stored in database, available through etraveler	Training on Process QC probe station and control software
402.02.03	Sensors	OT-QA-005	CMS DocDb Ref # 13384, 13390	OT-eng-008, OT-eng-028, OT-eng-37, OT-eng-045	PS/2S/MaPSA Radiation Tolerance	Neutron Irradiation and evaluation is carried out on a subset of sensors per batch to ensure radiation tolerance throughout production	Access to RINSC, post-irradiation Sensor/Process QC tests	N/A	Neutron Flux and Energy spectrum calibrated periodically	Test results stored in database, available through etraveler	Irradiation done professionally, evaluation as above
402.02.03	Sensors	OT-QA-006	CMS DocDb Ref # 13384, 13391	OT-eng-028, OT-eng-37, OT-eng-045	OT/PS/2S/MaPS A Radiation Tolerance	Proton Irradiation and evaluation is carried out on a subset of sensors per batch to ensure radiation tolerance throughout production	FNAL ITA, post-irradiation testing	N/A	N/A	Test results stored in database, available through etraveler	Irradiation done professionally, evaluation as above



Ex: QA Flowdown in Technical Requirements

Example: MIP Timing Detector ([CMS-doc-13536](#)) *Related QA activities*



ID	Old ID	Type	Requirement Text	Rationale/Notes	Parents	QA Activities
Survive Radiation	MTD-engr-001	requirement	The MTD must be able to operate efficiently up to an integrated luminosity of 4000 fb ⁻¹ , without any maintenance intervention for the barrel detector, whereas the endcap detector may be accessible during the HL-LHC era.	The MTD is expected to experience in the highest radiation region of ionizing radiation dose of up to 25 kGy and a hadron fluence of up to 2x10 ¹⁴ neq/cm ² in the barrel, and 690 kGy and 2x10 ¹⁵ neq/cm ² in the endcap at the end of lifetime.	MTD-sci-engr-01, MTD-sci-engr-02, MTD-sci-engr-06	MT-QA-010
Hit Multiplicity	MTD-engr-002	requirement	Modules will be arranged to provide detector coverage that ensures optimal association of tracks to MTD hits	In order to ensure that the PU removal and LLP searches make efficient use of the timing information, >90% of tracks needs to have precision timing information	MTD-sci-engr-06, MTD-sci-engr-08	MT-QA-004
Impact on the OT and HGCal performance and design	MTD-engr-003	requirement	Ensure that the installation, operation, and maintenance of the MTD does not impact the performance of the OT and HGCal, and does not introduce instabilities in their operation	MTD detector is designed to maintain independent thermal volumes in the tracker support tube for the BTL, and on the nose of the HGCal for the ETL, and low material budget	MTD-sci-engr-02, MTD-sci-engr-04	MT-QA-005
Integration and accessibility of the BTL detector	MTD-engr-004	requirement	The barrel timing layer (BTL) shall be integrated into the Tracker Support Tube (TST) within the mechanical specifications and within a time frame defined by the Tracker group.	The BTL section of MTD will be operated jointly with the Tracker. It will not be accessible after installation. Strict quality control of all components is required.	MTD-sci-engr-04	MT-QA-005
Accessability of the ETL detector	MTD-engr-005	requirement	The endcap timing layer (ETL) shall be mechanically accessible for servicing and module replacement during technical stops and long shutdowns	The ETL section of MTD may be accessed for repairs and replacements of faulty components, and should maintain an independent dry/cold volume which is isolated and operated separately from the HGCal	MTD-sci-engr-04	MT-QA-009
Module cooling	MTD-engr-006	requirement	Sensor temperatures shall be maintained below -20 C to maintain low Dark-Count-Rate (DCR) in BTL, and low leakage current in the ETL	Optimal performance of the BTL front end readout electronics requires operation of the sensors at low DCR. In the ETL compartment, the LGAD sensors need to be operated at low temperature to maintain high gain.	MTD-sci-engr-02, MTD-sci-engr-03	MTD-QA-004, 008



Subcomponent QA Plans and Procedures

Charges #6 & #8

- Process for creating plans and procedures well known and followed
 - Many existing documents for U.S. work from prototyping and from initial and phase 1 construction can be re-used: just need modifications or updates
- Status of individual procedures is adequate for stage of the project
 - Column in QA Activities spreadsheet ready to record procedures related to activity.
- Few detailed procedures readily reviewable now
 - Not finalized: Evolution during ongoing design/prototyping
 - Not timely: Many not applicable until much later
 - Not public: Procedures provided by CMS or collaborators

Ex 1: MTD Draft Subcomponent Procedures

- MTD example: [CMS-doc-13758](#)

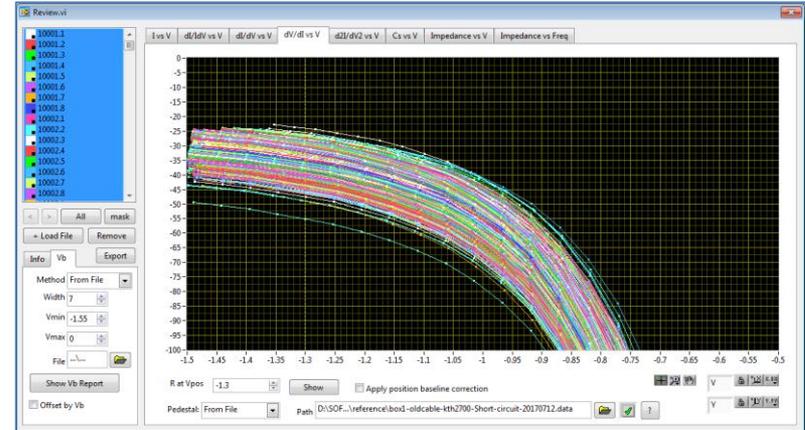
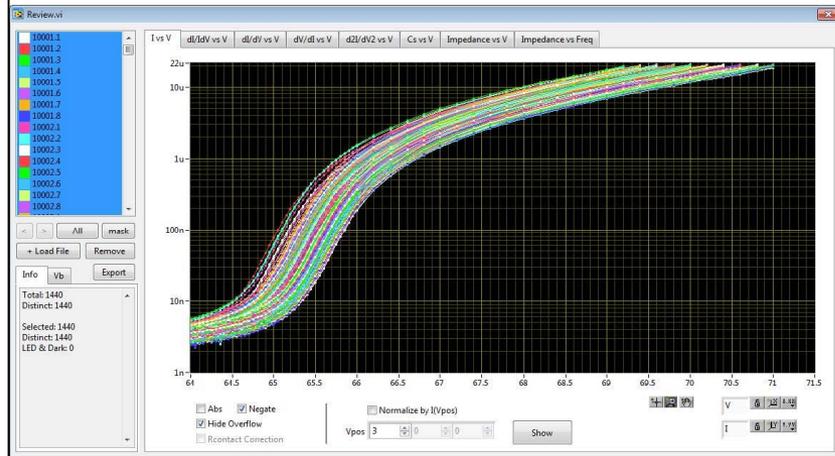
SiPM QC Plans for the Barrel Timing Layer

Introduction

US CMS has responsibility for the testing and quality control of 50% of the SiPM production for the Barrel Timing Layer, a total of just under 175,000 channels. The Notre Dame SiPM team at CERN will carry out this work. The various measurements and procedures will be based upon our previous experience with SiPMs for the Phase I upgrade of the HCAL detector.

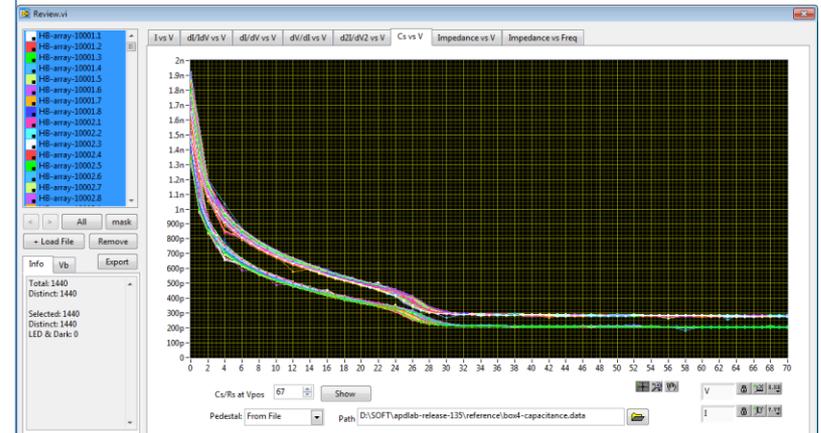
Measurements of each SiPM channel:

We will obtain IV curves for each channel, both at room temperature and at -30°C . IV curves taken without illumination are useful to find SiPM channels with various flaws. The IV curves taken with illumination are used to accurately determine the breakdown voltage (the voltage at which the device starts to operate) for each channel. The figure below shows IV curves with illumination taken for 1440 channels of SiPMs for the HB detector. The breakdown voltage (the voltage at which the device starts to operate with gain > 1) is determined by finding the voltage where the slope of this curve has its largest change.



Measurements on 2% of the SiPM channels:

Two more sets of measurements will be performed on 2% of the production SiPMs. First will be a measurement of the SiPM capacitance. Shown below are curves of capacitance vs bias voltage for HB production SiPMs. The capacitance asymptotically approaches a steady value as the bias voltage increases towards the breakdown voltage. The two distinct values correspond to the two SiPM sizes for HB – 2.8 mm diameter and 3.3 mm diameter.



Ex 2: Endcap Cal Draft Subcomponent Procedure

- Endcap Cal example: procedures currently in use at UCSB for the production of test beam silicon modules

Fabrication, Testing, Shipping and Receiving

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1

General safety precautions

- Handling any component or module
- Handling PCBs and sensors

Shipping and Receiving

- Receiving Baseplates
- Receiving PCBs
- Receiving Sensors
- Shipping modules
 - Quality control and safety
 - For single black boxes:
 - For Boxes that carry multiple modules:

Fabrication

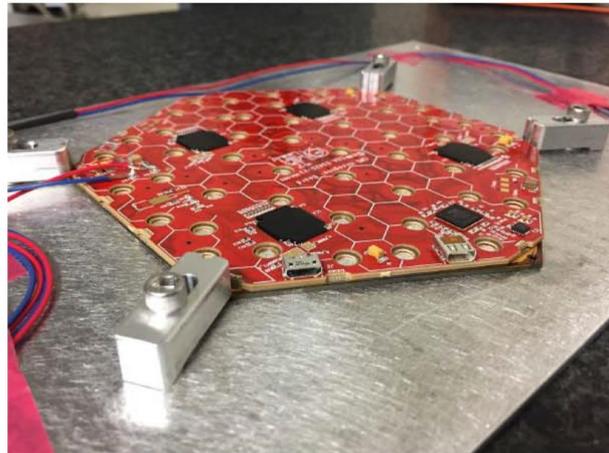
- Kapton to Baseplate
- Sensor to Baseplate
- PCB to Sensor
- Wirebonding and pull testing
 - Turning on Wire Bonder
 - Hexaboard Program
- Edge Program
- Pull Testing

Module and PCB testing

- Safety precautions
- DAQ without bias voltage
 - A PCBs
 - B Modules
 - C Running the data acquisition
- DAQ with bias voltage

Fabrication

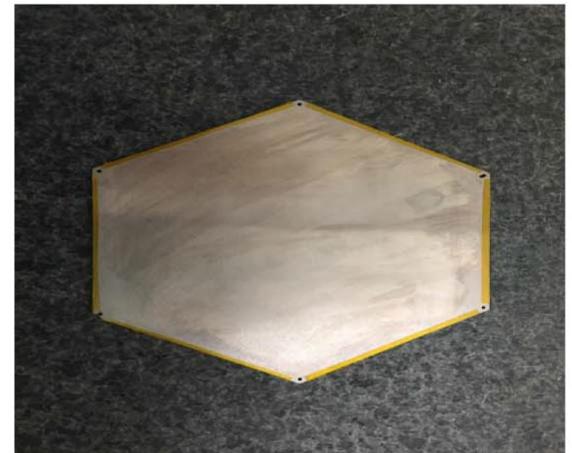
The construction of each module is a series of deliberate and careful steps. One must take great caution as each step introduces its own challenges which can bottleneck the whole process. For all of the fabrication steps, we use a 75um layer of Areldite 2011 epoxy. The first is placing a kapton layer with gold foil onto the baseplate of the module. The baseplate serves as the foundation for the rest of the sensor components. The base plates come in two types: Copper and Copper Tungsten. Both have varying thickness that vary from 0.6mm, 1.2mm to 2.2mm. The gold-coated kapton+silver epoxy is used for biasing the backside of the sensor and serves as insulating material between the baseplate and the silicon sensor. The kapton layer itself is 50 um and the gold layer is 50 um, creating a 100 um contribution for the whole module. The second step involves gluing the sensor onto the baseplate and kapton. The silicon has three different thickness: 120um, 200um and 300um. These are very delicate and careful handling is crucial. This step involves gluing on the baseplate and placing silver epoxy between the gold layer behind the sensor and the gold layer on the baseplate. The final step includes gluing on the circuit board onto the sensor. The circuit board is approximate 1.4mm. These are all important steps and great care must be taken at every corner to ensure that the module is functional.



(Image of completed module on carrier tray with HV cables attached)

Kapton to Baseplate

- 1) First, one must select a baseplate and ensure that it is flat enough for assembly. Having a warped baseplate can scratch the module during dispensing routines. One can press down the center of the baseplate and then shim the baseplate or use the dial to measure the height of the baseplate from the granite table. Subtract the lowest measurement from the highest measurement to get a rough measurement of how warped the baseplate is.
- 2) Next, once a suitable base plate has been chosen, one must tape kapton around the edges of the baseplate to make sure that there is not baseplate material under the sensor. To do this, cut some of the kapton tape (a few mm wide) and place it on the edges of the baseplate. This is done to prevent shorting from the baseplate to the sensor. Be careful to have good control of the thickness of the kapton take and not have it hang out too much from
- 3) Make sure to input the baseplate ID into the UCSB HGICAL database and assign a module number to the baseplate since a kapton layer will be placed on it. **Please do not put this off or write it on a piece of paper.** These things can get easily lost and can be a headache later.





Qualifications and Training

- U.S. CMS Project Managers and subproject leads responsible for ensuring that team members are adequately trained and qualified
 - See Endcap Cal example next slide
- U.S. CMS Leads and staff have varying level of experience and expertise with respect to QA
 - Most are selected based on demonstrated technical skills and experience as well as past project management and CMS experience
 - Some are already knowledgeable about formal QA
- On-the-job training provided through interactions with the CMS QA Managers, U.S. QA Coordinator, and experienced senior leads



Ex: Subproject QA Training

Aug 2018 Training Workshop for assembly of test beam modules for Endcap

QA/QC

Specifications

Silicon Modules Workshop

J. Strait, Fermilab



Why Quality Management

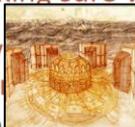
Quality Management – QA and QC – is nothing more and nothing less than a systematic way of making sure we don't screw up.

Even though we know planning and documenting

- to force us to really be
- to transmit that information
- to make sure that the

Experience shows that

There is a body of experience to exploit it for our own



Procedures and Database

Written, reviewed and approved procedures are a key element of how we "normally" assure quality in science projects.

- Exercise to think through the production process
- Tool for training those who will do the work
- Check list to ensure
- Revised and improved

The database is and

- Exercise to think through
- Companion to the particularly the QC
- Record of all key changes
- Allows trends to be
- Transmits necessary (cassettes) or for operation



References

- Fermilab QA Manual (<http://esh.fnal.gov/xms/ESHQ-Manuals/QAM>)
- Quality Assurance Plan for the US CMS HL-LHC Project (CMS-doc-13093)
- CMS Tracker Optical Links Quality Assurance Manual (EDMS 332290)
- CERN A&T Sector Quality Management (<https://quality.web.cern.ch/>)*
- Draft procedures for Fabrication, Testing, Shipping and Receiving of HGCALE silicon modules (https://indico.cern.ch/event/735080/contributions/3031803/attachments/1663326/2665718/UCSB_Module_Procedures_Draft_v01.pdf)
- HGCAL TDR, Chapter 13 (<https://cds.cern.ch/record/2293646/files/CMS-TDR-019.pdf>)
- UCSB Tracker Assembly web page (<http://hep.ucsb.edu/cms/assembly.php>)
- Presentation on Tracker module QA/QC (http://hep.ucsb.edu/cms/modqc_anlrev03.pdf)

Sample pages



Subproject QA Planning Status

Charges #6 & #8

- QAP implementation Plans captured in Appendix
- QA Activity Spreadsheets drafted and standardized
 - Initial activity identification with responsibilities, goals, related hardware
 - Post-TDR cross walk to technical requirements in progress (3 out 4 done)
- QA Activity Planning being finalized during ongoing design stage
 - Technical requirements being finalized
 - Actual QA/QC procedures being determined/defined
 - Training being determined, defined, and implemented
- Responses to June 2018 IPR recommendations completed (See back-up slides for details)



Summary

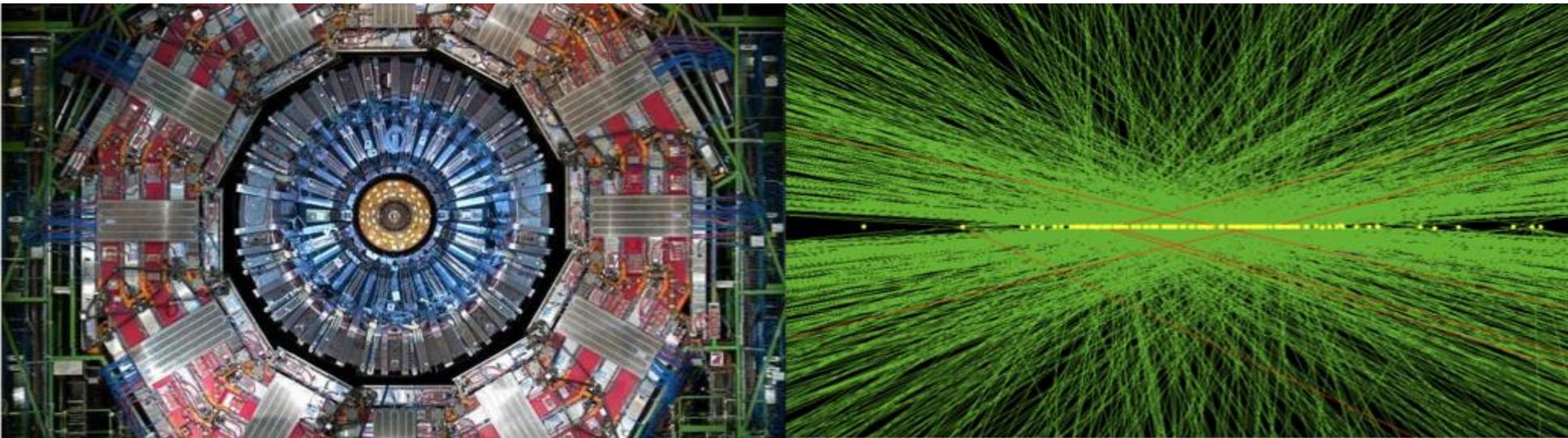
Charges #6 & #8

- Subprojects have well defined QA implementation plans
 - Follow the CMS Quality Assurance Plan
 - Also satisfy CMS requirements and procedures
- QA roles/responsibilities for each subproject are defined & assigned, from CMS down to participating institutions
 - Subproject leads are knowledgeable and practice good QA
- QA activities are identified and summarized in spreadsheets, linked to technical requirements
 - Finalizing details as design progresses
- Detailed subcomponent QA/QC procedures are evolving
 - Based on maturing design efforts and previous construction work

QA planning well developed and sufficiently mature for project stage. Project on track to be ready for CD-1 review



Back-up slides





Response to June 2018 IPR Recommendations

Charge #8

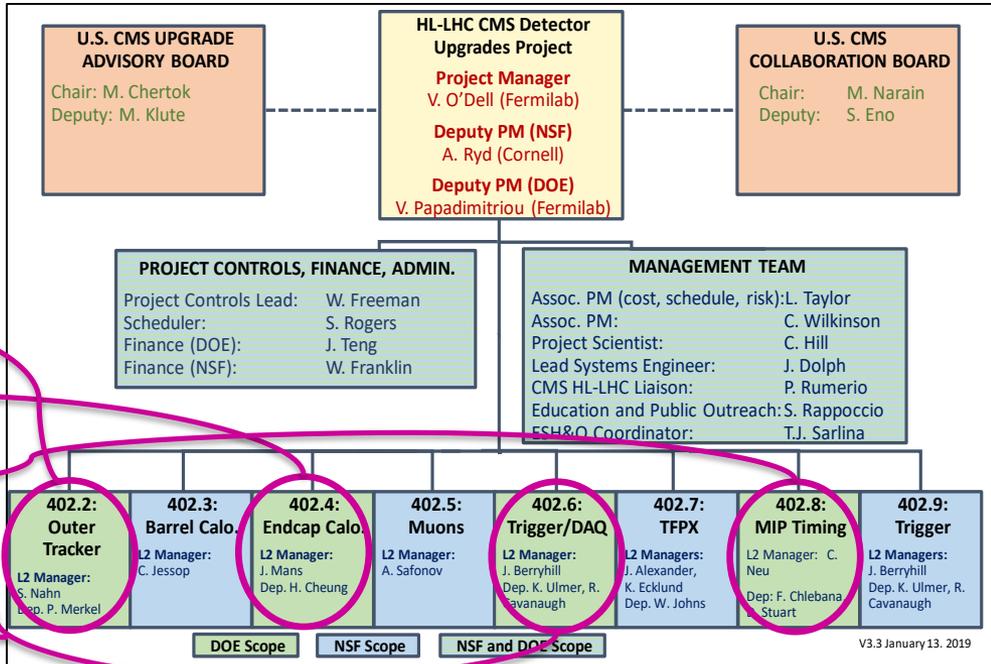
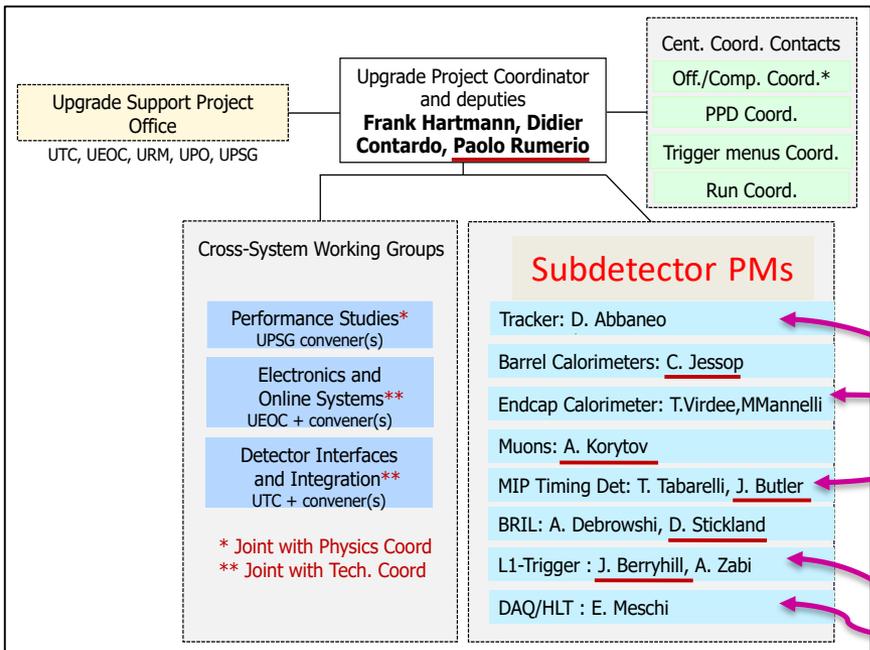
- 22.** Revise the ISM and QAP to accurately document the process for receipt, review, concurrence, coordination, and oversight of project specific plans and activities prior to the issuance of any contract instrument.
- ✓ Done. Covered in T.J. Sarlina talk on QAP. The QAP ([CMS-doc-13093](#)) follows FNAL procurement guidelines for vendors (see Section 6.8) and QAP process for U.S. participating institutions (See Section 7). Subproject implementation can be found on the OT subproject example on slide 12 of this talk and in the QAP Appendix ([CMS-doc-13093](#)). See section A.2.4.2 for OT or the corresponding section for other subsystems.
- 23.** Develop a clear plan for identification and documentation of codes, standards, requirements, and timing for inclusion.
- ✓ Done. Covered in T.J. Sarlina talk on QAP and found in the QAP, ([CMS-doc-13093](#)), Section 6.4.



Relationship with U.S. HL-LHC Project

CMS Organization

U.S. Organization



- QA procedures for each CMS subdetector (e.g. L1 Trigger) established by relevant CMS subdetector PM
- Corresponding U.S. CMS subproject L2 manager (e.g. 402.6) responsible for implementation, documentation, etc. within U.S. project to satisfy **both** CMS scrutiny **and** U.S. project/DOE requisites
- Facilitated by the integration of U.S CMS with CMS management
 - Sometimes, as for Trigger/DAQ, the CMs subdetector manager is the U.S. CMS L2 manager



CMS Subdetector: QA Roles and Responsibilities

- CMS Subdetector Leads
 - Oversight and management of each integrated detector subsystem, including efforts from all contributors.
- CMS Subdetector QA Managers (assigned by CMS)
 - Coordinate of QA processes across all collaborators.
 - Define/approve procedures for each component or subassembly
- U.S. QA Coordinator
 - Provides planning support & review/surveillance of participating institutions' QA
- U.S. CMS Subproject Leads (WBS L2, L3, L4)
 - Responsible for QA for their scope of work
- QA contact at participating institutions
 - Responsible for QA for their scope of work and communication with Subproject leads



QA Oversight for Participating Organizations

Participating U.S. CMS institutions must follow QA plans that satisfy CMS Subdetector requirements and the QAP.

- QA plans and procedures created collaboratively
 - U.S. L2, L3, L4 leads work with institutional technical and QA representatives and the US CMS QA Coordinator
 - U.S. leads ensure adherence to CMS requirements and approved procedures, subject to CMS review and approval process
 - Includes work under subawards to vendors or other participating institutions.
 - Institution staff responsible for verifying compatibility of QA plans to local institutional QA programs
- L2 lead and the US CMS QA Coordinator review and approve the QA plans and monitor/verify compliance.
 - Site visits may be required for QA plan approval and surveillance



Site Review/Audit Forms

- Standardized forms for Site Field Visit Audit Checklists and Reports

US-HL-CMS Quality Assurance Audit Field Checklist
WBS X.X.X Date:

/Contacts: Location:

1.	Material/Component Receipt	Yes	No	N/A
	Have acceptance criteria been defined by the organization?			
	Are the criteria written down, approved, and entered into a database?			
	Did the criteria change over time with documentation entered into a database?			
	If changes have occurred, have they been approved by appropriate authority?			
	Is data transmitted from last organization in a timely way and is it useful?			
	Do written procedures exist and are they followed?			
	Are personnel properly trained to conduct acceptance checks?			
	Are the results being documented in a consistent manner?			
	Are test results entered into a database?			
	Is all measuring and test equipment properly calibrated?			
	Are components and samples stored properly in secure and/or segregated locations to prevent damage or loss?			
2.	Quarantine of Deficient or Non-Conforming Product	Yes	No	N/A
	Are storage areas properly identified?			
	Is product labeling clearly visible and consistent?			
	Have non-conformance procedures been written and approved?			
3.	Personnel Training	Yes	No	N/A
	Do current, written procedures exist for each process?			
	Do posted instructions agree with authorized, written procedures?			
	Is there a process for informing or re-training workers when procedures change?			
	Are procedural changes reviewed for impact on the final product?			
4.	Acceptance Criteria For Finished Product	Yes	No	N/A
	Have acceptance criteria been defined by the organization?			
	Are the criteria written down, approved, and entered into a database?			
	Did the criteria change over time?			
	Have updated acceptance specs been approved and documented in a database?			
5.	Records, Logs, and Databases	Yes	No	N/A
	Have standard forms/spreadsheets been created to record data?			
	Is information entered in a timely and consistent manner?			
	Has the information been entered into a database?			

US HL CMS QA Audit Report for WBS X.X.X – (Insert WBS Name)
Level 2 Manager – (Insert Name)
(Date)

BACKGROUND:
The U.S. HL CMS Project Office conducts internal QA audits on operations related to construction of the experiment to ensure acceptance criteria have been defined and documentation is up to date. This WBS Section X.X.X audit, conducted by (Insert Names), examined operations at (Insert Facility) in (Insert Location) and (Any other locations if necessary).

FINDINGS AND OBSERVATIONS:

Section I - Material/Component Receipt, Testing, and Shipment

- Detail findings from field checklist and tie to specific Recommendations at the end of this document. (See Recommendation #X)
- List Best Practices as appropriate.

Section II - Quarantine of Deficient or Non-Conforming Product

- Detail findings from field checklist and tie to specific Recommendations at the end of this document. (See Recommendation #X)
- List Best Practices as appropriate.

Section III - Personnel Training/Operational Procedures

- Detail findings from field checklist and tie to specific Recommendations at the end of this document. (See Recommendation #X)
- List Best Practices as appropriate.